



Darwin's evolution theory, brain oscillations, and complex brain function in a new "Cartesian view"

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ABSTRACT

Comparatively analyses of electrophysiological correlates across species during evolution, alpha activity during brain maturation, and alpha activity in complex cognitive processes are presented to illustrate a new multidimensional "Cartesian System" brain function. The main features are: (1) The growth of the alpha activity during evolution, increase of alpha during cognitive processes, and decrease of the alpha entropy during evolution provide an indicator for evolution of brain cognitive performance. (2) Human children younger than 3 years are unable to produce higher cognitive processes and do not show alpha activity till the age of 3 years. The mature brain can perform higher cognitive processes and demonstrates regular alpha activity. (3) Alpha activity also is significantly associated with highly complex cognitive processes, such as the recognition of facial expressions. The neural activity reflected by these brain oscillations can be considered as constituent "building blocks" for a great number of functions. An overarching statement on the alpha function is presented by extended analyzes with multiple dimensions that constitute a "Cartesian Hyperspace" as the basis for oscillatory function. Theoretical implications are considered.

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1. Introduction: The New Cartesian View

In a recent essay Başar and colleagues theorized that, "In order to understand complex processes of brain–mind we have to analyze also brains of less developed living beings and compare them with the more intelligent and intuitive processes of the human mind" (Başar, 2005; Başar and Güntekin, 2007). Further, a new Cartesian System was introduced to analyze brain–body processes with its all histories and integration with all elements and the environment. The present essay provides an application of this new Cartesian concept to include evolution of species, brain maturation, and recognition of facial expressions. The overall goal is to characterize how neural processes can be approached by using several analytical windows.

The famous French mathematician and philosopher Henri Bergson (1907) studied Darwin (1859) and proposed a model basing on comparative physiology to describe memory and brain-to-mind processes. Authors such as Darwin (1859), James (1890) and Le Doux (1999) consider "emotion" to be a basic survival process that plays a major role in evolution and complex cognitive function. Emotion is related to a sensory modality – an internally directed sensory modality that provides information about the current state of the body (Solms and Turnbull, 2002). Hence, emotion adds a "sixth sense" to our conscious experience. The present thesis attempts to bridge philosophical concepts, electrophysiology during evolution of species, and emotion-processes related to recognition of facial expression. The essay

emphasizes the philosophical bases and empirical results from comparative physiology and human electrophysiology.

At first glance, it seems "ambitious and not in the usual trend" to bring together Aplysia ganglia and emotional behavior of the human brain with its unique "intuition¹ ability". But this is a rule of René Descartes (1840) from "Discours de la Méthode": Omit nothing, analyze everything, discard the wrong seeming judgments, and search basic and common elements of the problem under study. What we do in the present study is what Descartes strongly emphasized. We propose that what is needed is a new multi-coordinate "Cartesian System in Hyperspace".

2. Darwin's Theory

One of the most revolutionary developments in biological sciences has been Charles Darwin's (1859) introduction on "evolution of species". Darwin has worked within a framework of the living world as initiated earlier by Jean-Baptiste de Lamarck (1809). The theory of Darwin rests on two fundamental ideas: The first is the concept of "heritable variation". This is appearing spontaneously and at random as it was individual members of a population and is immediately transmitted through descendants. The second is the idea of "natural selection", which results from a "struggle for life". Only individuals whose hereditary endowments enable them to survive in a particular environment can multiply and perpetuate the species.

¹ Intuition is the act or faculty of knowing immediately, directly and holistically without rational processes and without being aware of how we know. It also is the channel or process through which realms of truth and knowledge are accessed.

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The genius French philosopher [Henri Bergson \(1907\)](#), who studied the work of Charles Darwin came to the conclusion that the superiority of the human brain in comparison to lower species is his ability of “intuitive and creative thinking”. [Henri Bergson \(1907\)](#) emphasized three types of mental abilities during evolution of species: instinct, intelligence, and intuition. Instincts are observed in low living beings as invertebrates. Intelligent behavior belongs also to functional properties of lower vertebrates and mammals. However, only human beings have the ability of intuition and are, according to [René Descartes \(1840\)](#) and [John Locke \(1690\)](#), what makes the human being different from other species. At the beginning of 20th century the proposal of Bergson could not be analyzed by means of electric recordings. This view gains importance from recent empirical studies and new analyses in which brain development of alpha activity during species evolution is characterized by asking fundamental questions considered below.

3. Unifying Questions to Understand Processes in the Brain and Nature

René Descartes stated that “Everything in the universe can be explained in terms of a few intelligible systems and simple approaches.” [Alfred Fessard \(1961\)](#) emphasized that the brain must not be considered simply as a juxtaposition of private lines, leading to a mosaic of independent cortical territories, one for each sense modality, with internal subdivisions corresponding to topical differentiations. What are principles dominating the operations of hetero-sensory communications in the brain? This knowledge needs an extensive use of multiple microelectrode recordings, together with a systematic treatment of data by computers (e.g., [Eckhorn et al., 1988](#); [Gray and Singer, 1989](#)).

[Fessard \(1961\)](#) further indicated the necessity of discovering principles that govern the most general or transfer functions of multi-unit homogeneous messages through neuronal networks. The transfer function describes the ability of a network to increase or impede transmission of signals in given frequency channels. The transfer function can be represented mathematically by frequency characteristics or wavelets constituting the main framework for signal processing and communication ([Başar, 1980](#); [Başar-Eroglu et al., 1992](#)). The existence of general transfer functions could be interpreted as the existence of networks distributed in the brain having similar frequency characteristics facilitating or optimizing the signal transmission in resonant frequency channels ([Başar, 1998](#)). In an electric system² an optimal transmission of signals is reached when subsystems are tuned to the same frequency range. Does the brain have such subsystems tuned in similar frequency ranges, or do common frequency codes exist in the brain?

The empirical results reviewed here imply a positive answer and provide a satisfactory framework to Fessard’s question. Brain tissues that contain selectively distributed oscillatory networks (delta, theta, alpha, beta, and gamma) constitute and govern mathematically the general transfer functions of the brain. According to Fessard’s prediction all brain tissues, both mammalian and invertebrates would have to react to sensitive and cognitive inputs with oscillatory activity or with similar transfer functions. The degree of synchrony, amplitudes, locations and durations or phase lags is continuously varying, but similar oscillations are most often present in the activated brain tissues ([Başar, 1999](#)). The general brain transfer functions manifested in oscillations strongly indicate that frequency coding is one of the major candidates to govern brain functioning.

4. Generalization of Descartes and Fessard to Brain–Body Interaction and to “Evolution of Species”

As noted above, [Fessard \(1961\)](#) posed a question similar to Descartes, who mentioned the possibility of the existence of some

common principles and rules governing the nature: Are there some general principles that govern the transmission of the signals in the brain? The relevant question of Alfred Fessard related to electrical signals in the brain can be extended and generalized for the Brain–Body integration. “Are there also some general transfer functions in functional interactions of the brain with the vegetative system and biochemical pathways? Do cranial nerves and the brain stem link the vegetative system to cortex and provides also cognitive/memory integration?” ([Başar and Güntekin, 2007](#)). Are there also some general transfer functions in electrical activity of nervous system during evolution of species?

[Fig. 1](#) illustrates representative evoked potentials from several species in order to characterize electrophysiological changes (or mutation of activity) during evolution ([Başar et al., 1999](#); [Bullock and Başar, 1988](#)). Electrophysiological signals across species consisting in recordings of spontaneous electrical activity and evoked potentials have been analyzed ([Başar et al., 1999](#); [Bullock and Başar, 1988](#)). In addition to the conventional electrophysiological recordings, oscillatory brain dynamics were applied to data from isolated ganglia of *Aplysia*, *Helix Pomatia*, and brains from low vertebrates as goldfish and ray. Cortical and sub-cortical structures of the cat brain and the scalp recordings from the human brain were also assessed, with delta, theta, alpha, beta, and gamma oscillations quantified.

During the evolution of species the central nervous systems of various living beings starting from invertebrates to low vertebrates, vertebrates, mammals and human brain went through great changes in anatomical structures and their biochemical pathways took place accompanied by changes in the electrical activity ([Bullock and Başar, 1988](#); [Bullock et al., 1995](#)). Invertebrates have less ample low frequency responses. In the fish brain slow evoked potentials are increased in comparison to the invertebrate ganglia. In the mammalian brain slow responses are much higher in comparison to the fish brain. Thus, the evolution also demonstrates a type of dynamic behavior.

A second type of dynamic change in the morphology takes place during maturation of the human brain. The brain of the fetus, the brain of the newborn baby, brains of 3-year-old children, and the adult brain have morphological differences especially in frontal lobes (see also [Solms and Turnbull, 2002](#)). In addition, during evolution of species and during maturation of the brain, a similar type of development is related to cognitive processes and more precisely to processes of thought. Important changes to evolution of species and maturation of the human brain are the increase of intelligent behavior, and at the final stages of both developments, the ability of creative processes in relation with the intuition and synthesis power. Neither babies nor low level living beings have creativity, decision making and intuition.

5. Electrical Neural Activity During Evolution of Species and Maturation of the Brain

[Fig. 2](#) illustrates a more detailed frequency analysis such that invertebrate ganglia have very low amplitudes in the 10 Hz frequency range ([Schütt et al., 1999](#)). The 10 Hz range activity in *Helix Pomatia* has maximal 10 μV peak-to-peak amplitudes. In the human brain scalp recordings 10 Hz activity can reach amplitudes up to 50 μV .

[Table 1](#) summarizes a data set accumulated over the last 20 years from laboratories in Ankara, Lübeck, and San Diego ([Başar et al., 1999](#)). The frequency positions of maxima in several species ranging from invertebrates to the human brain have been evaluated. In *Helix Pomatia* five types of ganglia are presented, in *Aplysia*’s cerebral ganglion two groups of measurements, in the ray mesencephalon and medulla, in goldfish telencephalon, mesencephalon and medulla, in the cat brain auditory cortex, reticular formation and hippocampus are presented. The human studies cover central, occipital, parietal and frontal areas. In the invertebrate ganglia, 10 Hz activity is scarcely obtained, whereas measurements of higher brain levels demonstrated more 10 Hz activity.

² The brain is a system with the ability to have electrophysiological transmission property. This means that the electrical tuning of the brain can be studied similar to the analysis of an electric circuit, for example a simple electronic device.

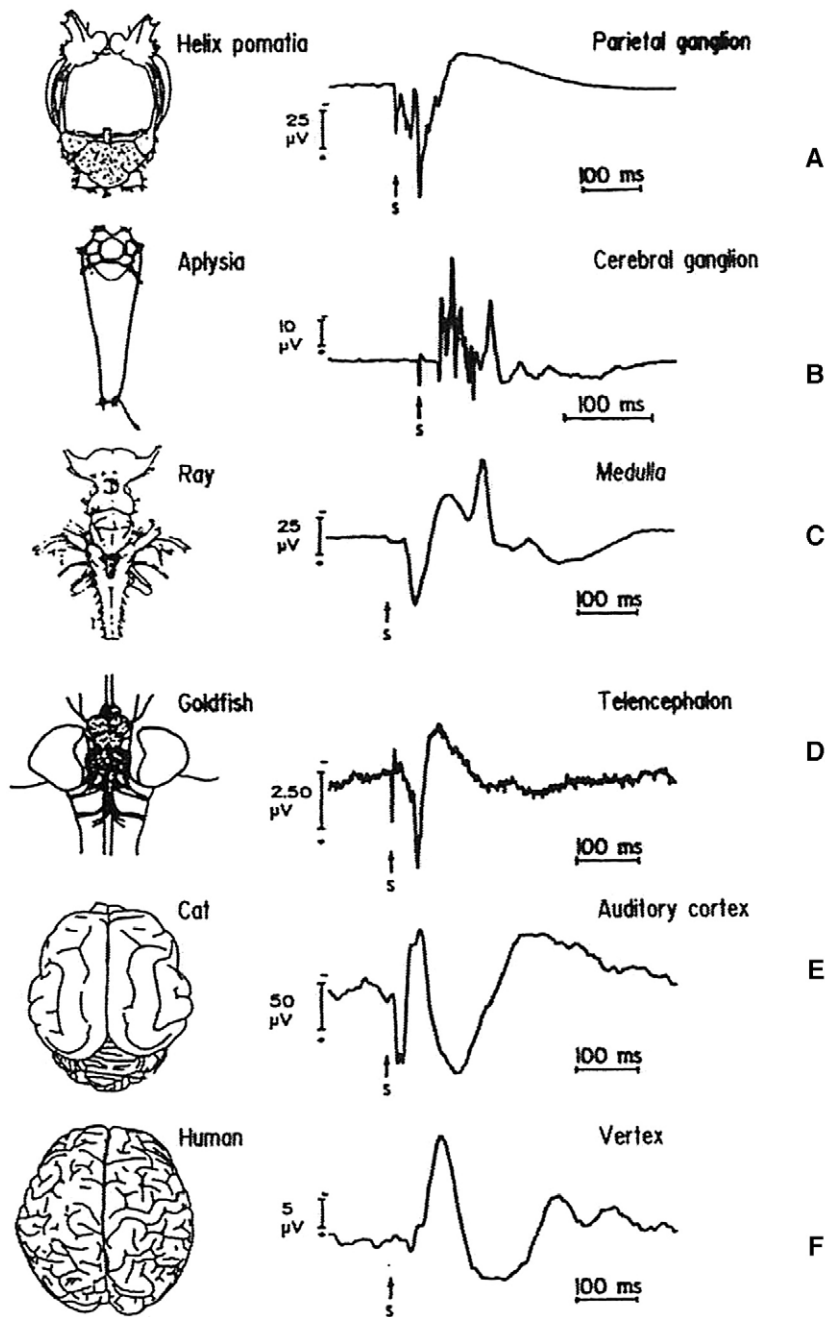


Fig. 1. The brains investigated are schematically presented together with the characteristic averaged evoked potentials from different loci: A and B, direct shock stimulus to afferent nerve; C: physiological stimulus of electroreceptors; D–F: acoustical stimulation (after Başar et al., 1999).

Table 1 also presents the “characteristic” frequency components observed in the samples of different brain structures of the ray and goldfish together with those of the invertebrate samples and the mammals (cat and human). The predominant frequency components of the mammalian cortex are usually found within a range not higher than 40 Hz. However, the reticular formation of the cat shows a dominant frequency component around 85 Hz. It is of interest that a similar high-frequency invariant (80–100 Hz) exists in goldfish medulla. The 15–30 Hz invariant also exists in all structures.

These findings revealed that the 10 Hz alpha oscillations can be pointed as a key indicator in evolution of species in ganglia of Aplysia and Helix Pomatia. In these ganglia 10 Hz oscillations were only scarcely recorded, but this activity increased in amplitudes in low vertebrates and in the cat brain in comparison to invertebrates. In the

human brain the alpha activity indicates high level wavelet entropy, with earlier studies also indicating that the alpha coherency in invertebrate ganglia is totally absent and reaches higher values from low vertebrates to the human brain (Bullock and Başar, 1988). All other oscillations are also somewhat changing during evolution of species. However, the changes of the alpha activity in the human brain are obvious in comparison to other frequencies. Accordingly, only alpha activity is analyzed, and it is also associated with a sudden change in human ability that can be called “intuition”. Cats or monkeys are intelligent creatures, however, they have no intuitive behavior and since yet they have not performed any discoveries.

Table 2 includes grand averages of coherences of subdural and depth recordings from the human brain (Bullock et al., 1995). It is noteworthy that high coherences were not observed in invertebrates

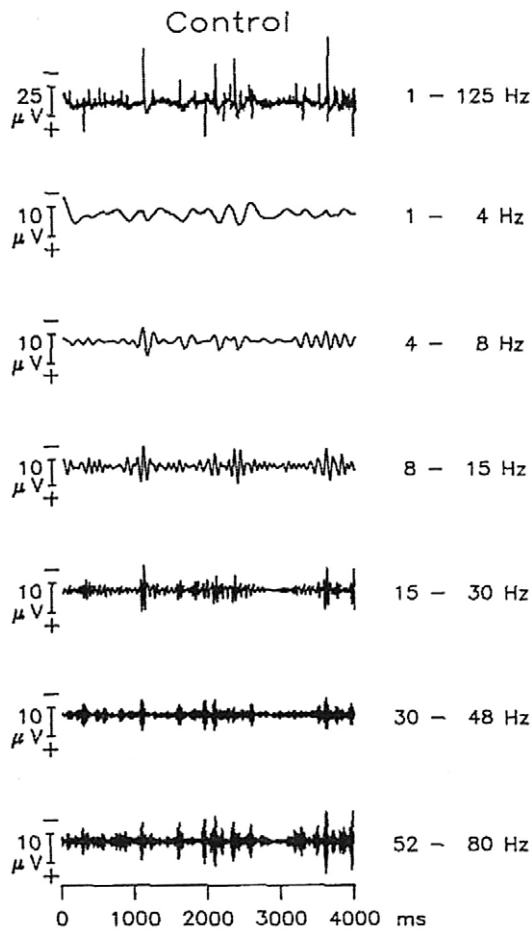


Fig. 2. Helix Pomatia: A typical time signal (ca. 4 s) of the ongoing activity with a modest number of spikes in the neuropile of isolated visceral ganglion; wide-band (1–125 Hz) and pass-band components (1–4, 4–8, 8–15, 15–30, 30–48, 52–80 Hz) (after Schütt et al., 1999).

and low vertebrates, so that it can be proposed that the changes in coherence, that is the amplitude and entropy³ of alpha oscillations are key indicators for the development of mental activity during evolution of species. Coherence and entropy are interwoven: If the electrical activity of a nervous tissue is high, the order in the electrical activity is higher, thus the entropy lower. Is the superiority of the human brain manifested by intuition and creativity strongly correlated with its lower entropy alpha activity in comparison to alpha activity in lower species? It is proposed that the increase in the alpha entropy is a good candidate to show the superiority of the human brain to less developed brains.

6. The Role of Alpha Activity in the Maturing Brain

Children do not have alpha activity till the age of 3 years. Cognitive performance of children is also not completely developed in the age of 3 years. Young adults have better cognitive performance and speech ability in comparison to children, and their alpha activity is also highly increased. Hence, during the maturation of the human brain the alpha activity also undergoes a type of evolution termed here “microevolution”. As the alpha activity reaches higher amplitudes and almost sinusoidal shapes its entropy is decreasing. This means that the

³ The entropy of a signal can be simply defined as follows: If the time course of the signal is regular (for example similarity with sinusoidal) the entropy is low. On the contrary, if the time course of a signal looks irregular and noisy its entropy is high. Accordingly, a regular alpha activity of the human brain is clearly a low entropy signal, whereas less regular 10 Hz signals of Aplysia are high entropy signals.

Table 1

Maxima of EEG frequency characteristics in different species (after Başar et al., 1999)

Frequency band (Hz)	1–8	8–15	15–30	30–48	52–100
Species	Maxima in frequency characteristics (Hz)				
Helix					
Pleural r.	5	–	20	–	–
Parietal r.	2	–	16	40	65
Visceral	2	–	16	35	60
Parietal l.	2	–	16	50	–
Pleural l.	2	9	18	40	75
Aplysia					
Group I	2	to	20	40	100
Group II	3	–	25	–	60
Ray					
Mesencephalon	5	–	28	–	–
Medulla	–	9	16;24	40	–
Goldfish					
Telencephalon	3	10	–	35	90; 100
Mesencephalon	–	–	–	30	80; 100
Medulla	–	–	–	–	80; 90
Cat					
GEA	5	–	18	40	80
RF	5	11	25	40	85
HI	5	12	–	45	–
Human					
C _z	4	8	25	40	–
O	3.5	10	25	45	75
P	6	10	20	40	70
F	4	8	20	35; 45	–

maturing brain's alpha activity is involved with transition from a high entropy state to a low entropy state. It is readily assumed that the higher cognitive ability of the adult brain in comparison to the child brain is accompanied with the entropy decrease with its alpha activity.

The question again arises: “What is electrically changed during evolution of species, by assuming that the frequency codes were kept almost invariant?” Four types of differentiations have been observed in spite of similar response frequencies: (1) The amplitudes of slow EEG oscillations were increased from invertebrates toward the human brain. (2) The synchrony of oscillations was increased also during the evolution. (3) No significant coherences were found in the neural networks of the invertebrates (Bullock and Başar, 1988; Bullock et al., 1995). On the contrary, in mammals and the human brain high coherences between distant structures are recorded. (4) The entropy of electrical oscillations diminishes during evolution, predominantly for 10 Hz oscillations (there are almost no 10 Hz oscillations in Helix or Aplysia, in the human cortex there are coherent very regular 10 Hz oscillations).

From these four important changes the decrease of entropy appears to have a significant role in the growth of intelligence and intuition. Hebb (1949) proposed perceptual inputs or thoughts would increase the connectivity between neural assemblies, and Edelman (1978) suggested that this view can open the way to selective neural groups. Increase of connectivity and building of selective neural groups could induce greater order in neural assemblies in hippocampus, cerebral cortex and cerebellum cortex of mammals. The demonstration of regular cell-orders does not exist in invertebrates and lower vertebrates, so that a decrease of entropy in the shape of anatomical structures is not found. Furthermore, the lower entropy of electrical oscillations (at least 10 Hz) shows a parallelism to the development of lower entropy of neural structures. Hence, during evolution the entropy of structural organization and

Table 2

Grand averages of coherence (C) for nearest neighbor pairs of electrodes 9–10 mm apart

Filter band (Hz)	2–5	5–8	8–13	13–20	20–35	35–50
Subdural C10 mm	0.47	0.47	0.43	0.40	0.34	0.38
Depth probe C9 mm	0.48	0.61	0.55	0.49	0.49	0.51

Data pooled from samples in the awake, alert state, for six standard frequency bands. C10 mm from subdural recordings is based on $N=2876$ values from 14 to 22 pairs and at least three 20 s epochs from each of the 7 patients with awake data (after Bullock et al., 1995).

of electrical oscillations is decreased, which leads also to new discoveries or inventions by human beings. How does this decrease of entropy during evolution open the way to mental processes? Alternatively, are the related mental processes able to increase connectivity between neural populations and accordingly to the forming of modifications in ordered neural structures and regular alpha activity? Both ways are possible, and it can even be proposed that both ways provide a recurrent and reciprocal activation of the incorporation of low entropy and higher nervous activity.

This view leads back to Bergson's creative evolution. At the turn of twentieth century electrical activity of the brain (especially EEG oscillations) and anatomical knowledge of neural structures were not yet discovered. Moreover, Hebbian mechanisms or results on the maturation of human brain were unknown. Bergson's efforts to find parallelisms between evolution of species and evolution of thought were quite remarkable, and it should be emphasized that his proposed association between human brain function and intuitive solutions or creation is highly significant. Developed mammalian (like cats) certainly have this kind of performance and are more intelligent than lower vertebrates, as they can develop new abilities of hunting and searching. Cat brains show a higher degree of spontaneous and evoked alpha and can selectively respond to sensory stimulation, with P300 potentials observed upon cognitive loading (Başar-Eroglu et al., 1991). However, abundant and high amplitude synchronized spontaneous 10 Hz activity similar to human is absent in the cat brain, with an increase in the evolution of species in shape and abundance of alpha activity only found in humans. Human beings have the ability of speech, they can solve geometry problems, and they can invent new machines and can search the cause of gravitation and the motion of the planetary system. Is the evolution of alpha activity a consequence of the highly sophisticated human brain in comparison to the cat? Or do the creative evolution and the creativity of the human brain trigger this alpha activity?

Fig. 3 illustrates global waveform shapes of alpha activity during evolution of species and during maturation. Scales of time and amplitude are not provided, as only approximate measures are needed to reflect the global differentiation of spontaneous alpha amplitude activity and alpha responses. In invertebrate's ganglia illustrated on the left, only low amplitude and irregular spontaneous activity is observed. Because of the irregular behavior of the oscillatory activity, the entropy is high. In low vertebrates (fish brain) the alpha activity is higher in comparison to the recordings in invertebrate ganglia and

Summary of alpha in the maturing and evolving brain

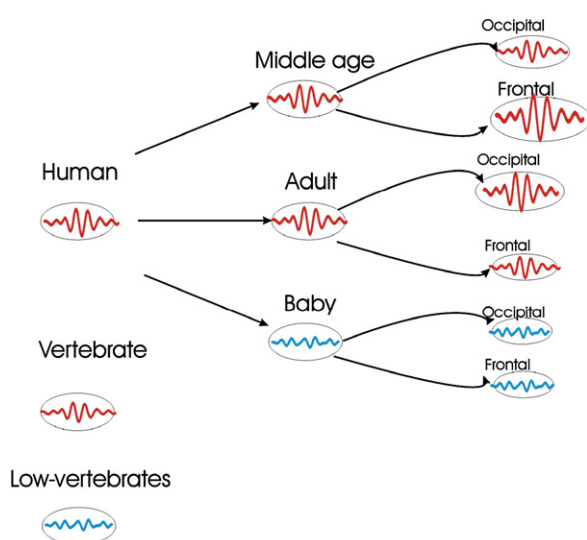


Fig. 3. Globally illustrated waveform-shapes of alpha activity during evolution of species and during maturation of the human brain.

more regular. This illustration does not include the cat brain, which shows larger more regular alpha activity and is described in Table 1.

In the human brain the amplitudes illustrated on the right panel, the alpha activity depicts drastic changes during maturation. Babies do not have alpha activity till the age of 3 years. There are also no frontal or occipital alpha responses during this period of life. Scalp recordings of some babies yield a type of weak alpha activity in the occipital locations at the beginning of the third year of life (Başar-Eroglu et al., 1994), and adult cognitive development associated with large occipital alpha. However, frontal alpha responses of the adults are low and sometimes are not at all observed in the adult brain. In the middle aged subjects, a reversal between occipital and frontal recordings is observed in subjects older than 55 years occipital alpha responses are decreased and frontal alpha responses are highly increased (Başar et al., 1997).

In summary of Fig. 3, two major changes in alpha activity are observed: (1) Increase of amplitudes and decrease of alpha entropy (i.e., decrease of the order of the shape of alpha) during evolution of species. (2) Higher alpha activity during maturation of the brain, and decrease of occipital alpha activity in elder subjects with a parallel increase of frontal alpha activity. In both cases, morphological changes in the brains are observed.

7. Manifestation of Alpha in a Highly Complex Brain Function

James (1890) conceived emotion in terms of a sequence of events that starts with the occurrence of an arousing stimulus and ends with a passionate feeling, a conscious emotional experience. Le Doux (1999) states that a major goal of emotion research is still to elucidate this "stimulus-to-feeling" mechanism to figure out, what kinds of processes take place between the stimulus and the feeling. The role of the spontaneous alpha and of the alpha response in evolution of species and the maturing brain has been emphasized above. Emotion is likely a type of "sixth sense" that is anchored to cognitive processes. The important link between emotional and basic mental processes can be illustrated with examples of how alpha activity is related to recognition of facial expressions. The goal is to highlight how alpha oscillations are not only a mutating signal in the evolution of species but also a sign of mutation during brain maturation. Thus, alpha activity is anchored to many functional processes including complex ones and is a universal building block of the CNS-functioning.

Fig. 4 illustrates the topology of grand averaged alpha responses, with alpha response amplitude from an angry face stimulus larger than that from a happy face stimulus at the posterior sites (T_5 , P_3 , P_4 , O_1 and O_2). The peak-to-peak amplitudes of the alpha responses were significantly larger following angry face stimulations compared to happy face stimulations at T_5 ($p=0.005$), P_3 ($p=0.023$) and O_2 ($p=0.021$) locations. Statistically reliable differences in alpha amplitudes were only found between angry and happy expressions based on individual stimulus valence ratings selected for the ERP data analysis (Güntekin and Başar, 2007).

The increase of alpha response to light stimulation can be originated for several reasons, as it is physiologically expected that changes in visual stimulation should influence the electrical activity in the primary visual areas (Başar, 1999). However, the different results related to angry and happy face stimulations indicate that the occipital areas are involved in fine functional adjustments related to emotional and selective attention processes. It is also possible that the occipital cortex, which is involved in phyletic memory, could have additional properties to link emotional memory with phyletic memory (Başar, 1999).

8. Holistic Brain Function: Multiplicities and New Cartesian Systems

A new Cartesian system for understanding the brain function over a large scale by using multiple approaches has been introduced so that a biological system (the brain) can be understood by integrating all histories of its development, evolution, and functional multiplicities

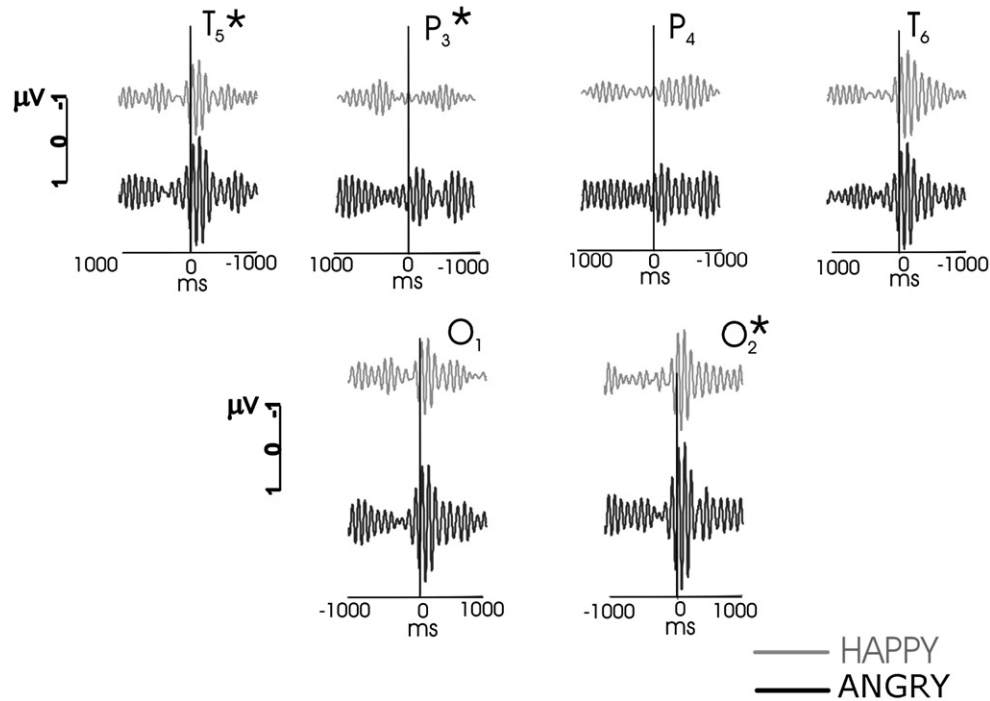


Fig. 4. Selective distribution of the grand averages of filtered (9–13 Hz) EEG-ERPs from angry face and happy face stimuli. Alpha responses to angry face stimuli are represented by a black line and alpha responses to happy face stimuli are represented by a grey line. Stimulation was applied at 0 ms T time point. The histograms indicated with large asterisks indicate statistical results (after Güntekin and Başar, 2007).

(Başar and Güntekin, 2007). This perspective includes in the analysis of any Brain–Body–Mind construct, uncertain causalities and consequently “multiple uncertain causalities”. These multiple causalities originated from: (1) Nonlinear properties of the vegetative system (irregularities in biochemical transmitters, cardiac output, turbulences in the vascular system, respiratory apnea, nonlinear oscillatory interactions in peristalsis); (2) nonlinear behavior of the neuronal–electricity (for example chaotic behavior of EEG); (3) genetic modulations, and (4) other physiological entities such as the nonlinear proprieties of physical processes in the body. This approach entails the need of a hyper-probabilistic Cartesian system to describe and analyze the processes in the brain–body–mind system.

Adding to this construct emotions and creativity, this “New Cartesian System” is more than hyper-probabilistic, it is a *nebulous* system, since it predicts the future only in a nebulous way. However, predictions on brain–body–mind integrations using this reasoning chain can be made. Analysis from a general systems theoretical approach emphasizes the effectiveness of the parallelism to “Quantum Dynamics” as model to elucidate structures of several processes in nature. Following this viewpoint it is proposed here that the processes or mechanisms of the brain–body–mind system can be analyzed and predicted by using the Brain-S-Matrix and Brain Feynman Diagrams recently introduced (Başar and Güntekin, 2007). The Nebulous Cartesian System is exactly this. At his time undertaking his genius step, Descartes did not possess the knowledge of today on physiology and modern physics. The time has come to consider such a New Cartesian System.

An advantage of this new Cartesian system is assessing the functional correlates of alpha activity by studying records of alpha activity in multiple areas of the human brain through the application of diverse sensory–cognitive inputs. Further, alpha activity should be measured in the maturing human brain (microevolution) by application of several sensory–cognitive strategies. Further, it is important to observe changes of spontaneous and evoked activity in pathological conditions (Başar-Eroglu et al., 2007; Yener et al., 2007). The study of alpha activity during the evolution of species is crucial to approach functions of alpha activity in general and in all its histories (alpha activity in macro-evolution).

In the Introduction, the view of Henri Bergson was described by stating that the intuition is the ability of the human brain which makes it superior to all type of brains. Accordingly, the alpha activity is a candidate to be representative of intuitive behavior, since the human alpha is superior to all type of 10 Hz activity in lower species. Accordingly, emphasis on the necessity of using a new Cartesian system for understanding of brain function to approach the functional correlates of spontaneous alpha activity and of alpha response, it seems evident that the use of a “Cartesian System in Probabilistic Hyperspace⁴” is a likely starting point. Only, after performing the analysis of the alpha activity in this new Cartesian system knowledge of alpha activity may be used as a key indicator in several processes. Moreover, considering alpha activity as a type of mutation, this view reflects a type of hereditary behavior that supports that of Charles Darwin (1859) in his theory on evolution of species.

9. Conclusions

(1) Alpha activity grows during evolution. Increase of alpha during cognitive processes and decrease of the alpha entropy during evolution provide an indicator for evolution of brain cognitive performance. (2) Children younger than 3 years are not able to produce higher cognitive processes and do not show alpha activity till the age of 3 years. The mature brain has the ability to perform higher cognitive processes and shows regular alpha activity. (3) Alpha activity also has significant contribution in highly complex processes, for example, in recognition of facial expressions. Brain oscillations, therefore, can be considered as building blocks that take part in a great number of functions. (4) A general statement on the alpha function is only possible by extended analyses in a Cartesian system with multiple dimensions, thus constituting a “Hyperspace”. (5) The mutation of alpha in amplitude, shape, and entropy during evolution of species are prominent examples. Thus, the data and theory appear to support the transformational character of Darwin’s theory.

⁴ Hyperspace is a coordinate system with more than three dimensions.

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